

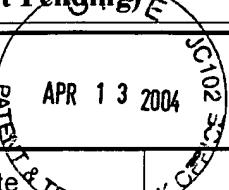
04-14-04

**TRANSMITTAL LETTER**  
**(General - Patent Pending)**

Docket No.  
 TSR-10002/38

In Re Application Of: **John Hilfinger et al.**

APR 13 2004



Serial No.

10/706,738

Filing Date

November 12, 2003

Examiner

Group Art Unit

Title: **METHODS AND COMPOSITIONS OF GEGNE DELIVERY AGGENTS FOR SYSTEMIC AND LOCAL THERAPY**

**TO THE COMMISSIONER FOR PATENTS:**

Transmitted herewith is:

1. Petition to Obtain Filing Date
2. Petition Fee of \$130

in the above identified application.

No additional fee is required.

A check in the amount of \$130.00 is attached.

The Director is hereby authorized to charge and credit Deposit Account No. 07-1180 as described below.

- Charge the amount of
- Credit any overpayment.
- Charge any additional fee required.

Signature

Dated:

April 13, 2004

Avery N. Goldstein, Reg. No. 39,204  
 Attorney for Applicant  
 Gifford, Krass, Groh, Sprinkle,  
 Anderson & Citkowski, P.C.  
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EV435301293US

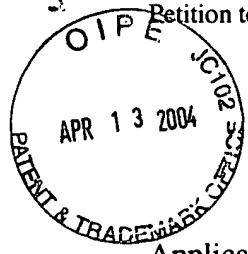
I certify that this document and fee is being deposited on April 13, 2004 with the U.S. Postal Service as first class mail under 37 C.F.R. 1.8 and is addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. **EXPRESS MAIL**

Signature of Person Mailing Correspondence

Janice R. Kuehn

Typed or Printed Name of Person Mailing Correspondence

CC:



Serial No. 10/706,738  
Petition to Obtain Filing Date

Attorney Docket No. TSR-10002/38

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: John Hilfinger et al.

Serial No.: 10/706,738

Filing Date: November 12, 2003

For: METHODS AND COMPOSITIONS OF GENE DELIVERY  
AGENTS FOR SYSTEMIC AND LOCAL THERAPY

---

PETITION TO OBTAIN FILING DATE

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

In accordance with 37 CFR Section 1.53(b), Applicant hereby requests grant of the filing date of November 12, 2003 and the inclusion of the misplaced pages.

Statement of Facts

On November 12, 2003 Applicant filed a utility patent application that is a non-provisional of U.S. Provisional Patent Application No. 60/425,379, filed November 12, 2002. The utility patent application was assigned Serial No. 10/706,738. The utility patent application incorporated by reference the text of U.S. Provisional Patent Application No. 60/425,379. (See page 1 of specification).

The entire patent application transmittal as originally filed is included herewith at Exhibit

A.

As part of the utility patent application submission a return receipt postcard was provided (transmittal documents, page 2 of 4, item 14). A copy of the return receipt postcard is attached hereto as Exhibit B. The return receipt postcard indicated that the five pages of claims were not received as part of the submission package. A telephone call to OIPE resulted in the recommendation that we delay any inquiry until after image file wrapper capture had been completed.

On February 25, 2004, a paralegal in our office, Janice Kuehn, who had initially worked to prepare the transmittal for the above-referenced utility patent application, entered the Patent Application Information Retrieval system (PAIR) using our customer number and identified not only the omission of five pages of claims according to the return receipt postcard, but also that the specification noted on the postcard as having 27 pages numbered only 12 pages upon image file wrapper capture. Subsequent phone calls were made to Ms. Dalord Dillard and Mr. Kevin Diggs of OIPE in order to request recovery of the original mailing material corresponding to this case in order to locate the missing specification and/or claims pages. These telephone communications attempting to gain additional information from Ms. Dillard and Mr. Diggs have continued from late February 2004 through until April 5, 2004. As of April 5, 2004, no information has been made available to Applicant by OIPE with respect to the content of the original mailing materials.

In light of the acknowledgement provided in the postcard (Exhibit B) indicating the acceptance of 27 pages of specification, Applicant hereby petitions to have the missing 15 pages of specification (pages numbered 13-27 inclusive) restored to the application file.

The declaration of Janice R. Kuehn attached as Exhibit C details the procedure by which the application submission was prepared and is provided to evidence a procedure that makes the

omission from the utility patent application submission packet of fifteen pages of specification or five pages of claims highly unlikely.

As a separate basis for the granting of the filing date of November 12, 2003 to the above-referenced utility patent application is the fact that U.S. Provisional Patent Application Serial No. 60/425,379 was incorporated by reference. The full text of Provisional Patent Application Serial No. 60/425,379 is found at appended Exhibit D. As the instant utility application incorporates by reference this provisional application which itself had patent claims appended thereto, it is submitted that this represents an independent basis for the grant of the original filing date and the subsequent filing of a preliminary amendment to include the missing five pages of claims.

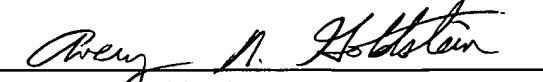
Petition Fee

Provided herewith is a petition fee under 37 CFR Section 1.17(i). Request for a refund of the petition fee is requested if it is determined that the pages of specification numbered 13-27 inclusive and claim pages numbered 28-32 inclusive (corresponding to claims 1-25) are subsequently determined to in fact have been received by the PTO along with the evidence provided herein of such deposit.

Insertion of specification pages 13-27 inclusive of the specification is requested. Acceptance of the missing five pages of claims corresponding to claims 1-25, or an

acknowledgement that through the incorporation of the provisional application including claims that the present application will be accorded a filing date of November 12, 2003 is requested.

Respectfully submitted,



Avery N. Goldstein  
Registration No. 39,204  
Gifford, Krass, Groh, Sprinkle,  
Anderson & Citkowski, P.C.  
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(248) 647-6000

Attorney for Applicant

ANG/gs  
Enclosures

GS-W:\Word Processing\ang\TSR10002-PetitionForFilingDate.doc

**CERTIFICATE OF MAILING BY "EXPRESS MAIL"**

"EXPRESS MAIL" MAILING LABEL NUMBER EV435301293US

DATE OF DEPOSIT April 13, 2004

I hereby certify that this paper or fee (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service "Express Mail Post Office To Addressee" Service under 37 CFR 1.10 on the date indicated above and is addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

  
Janice R. Kuehn

# UTILITY PATENT APPLICATION TRANSMITTAL

## (Small Entity)

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*



Docket No.  
TSR-10002/38

Total Pages in this Submission  
52

**TO THE COMMISSIONER FOR PATENTS**  
Mail Stop Patent Application  
P.O. Box 1450  
Alexandria, VA 22313-1450

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

**METHODS AND COMPOSITIONS OF GENE DELIVERY AGENTS FOR SYSTEMIC AND LOCAL THERAPY**

and invented by:

John Hilfinger, Blake Roessler, and Phillip Kish

If a **CONTINUATION APPLICATION**, check appropriate box and supply the requisite information:

Continuation    Divisional    Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Which is a:

Continuation    Divisional    Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Which is a:

Continuation    Divisional    Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Enclosed are:

### Application Elements

1.  Filing fee as calculated and transmitted as described below
2.  Specification having 34 pages and including the following:

- a.  Descriptive Title of the Invention
- b.  Cross References to Related Applications (*if applicable*)
- c.  Statement Regarding Federally-sponsored Research/Development (*if applicable*)
- d.  Reference to Sequence Listing, a Table, or a Computer Program Listing Appendix
- e.  Background of the Invention
- f.  Brief Summary of the Invention
- g.  Brief Description of the Drawings (*if filed*)
- h.  Detailed Description
- i.  Claim(s) as Classified Below
- j.  Abstract of the Disclosure

EL 983172102 US



25006

PATENT TRADEMARK OFFICE

**UTILITY PATENT APPLICATION TRANSMITTAL**  
**(Small Entity)**

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

Docket No.  
TSR-10002/38

Total Pages in this Submission  
52

**Application Elements (Continued)**

3.  Drawing(s) (*when necessary as prescribed by 35 USC 113*)
  - a.  Formal Number of Sheets \_\_\_\_\_ 7
  - b.  Informal Number of Sheets \_\_\_\_\_
4.  Oath or Declaration
  - a.  Newly executed (*original or copy*)  Unexecuted
  - b.  Copy from a prior application (37 CFR 1.63(d)) (*for continuation/divisional application only*)
  - c.  With Power of Attorney  Without Power of Attorney
  - d.  **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s) named in the prior application,  
see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5.  Incorporation By Reference (*usable if Box 4b is checked*)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6.  CD ROM or CD-R in duplicate, large table or Computer Program (Appendix)
7.  Application Data Sheet (See 37 CFR 1.76)
8.  Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all must be included*)
  - a.  Computer Readable Form (CFR)
  - b.  Specification Sequence Listing on:
    - i.  CD-ROM or CD-R (2 copies); or
    - ii.  Paper
  - c.  Statement(s) Verifying Identical Paper and Computer Readable Copy

**Accompanying Application Parts**

9.  Assignment Papers (cover sheet & document(s))
10.  37 CFR 3.73(B) Statement (when there is an assignee)
11.  English Translation Document (if applicable)
12.  Information Disclosure Statement/PTO-1449  Copies of IDS Citations
13.  Preliminary Amendment
14.  Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15.  Certified Copy of Priority Document(s) (if foreign priority is claimed)
16.  Certificate of Mailing  
 First Class  Express Mail (*Specify Label No.*): EL 983172102 US

**UTILITY PATENT APPLICATION TRANSMITTAL  
(Small Entity)**

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

Docket No.  
TSR-10002/38

Total Pages in this Submission  
52

**Accompanying Application Parts (Continued)**

17.  Applicant claims small entity status. See 37 CFR 1.27.

(Optional) Small Entity Statement(s) - Specify Number of Statements Submitted: \_\_\_\_\_

18.  Additional Enclosures (*please identify below*):

**Request That Application Not Be Published Pursuant To 35 U.S.C. 122(b)(2)**

19.  Pursuant to 35 U.S.C. 122(b)(2), Applicant hereby requests that this patent application not be published pursuant to 35 U.S.C. 122(b)(1). Applicant hereby certifies that the invention disclosed in this application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication of applications 18 months after filing of the application.

**Warning**

*An applicant who makes a request not to publish, but who subsequently files in a foreign country or under a multilateral international agreement specified in 35 U.S.C. 122(b)(2)(B)(i), must notify the Director of such filing not later than 45 days after the date of the filing of such foreign or international application. A failure of the applicant to provide such notice within the prescribed period shall result in the application being regarded as abandoned, unless it is shown to the satisfaction of the Director that the delay in submitting the notice was unintentional.*

**UTILITY PATENT APPLICATION TRANSMITTAL**  
**(Small Entity)**

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

Docket No.  
TSR-10002/38

Total Pages in this Submission  
52

**Fee Calculation and Transmittal**

**CLAIMS AS FILED**

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	25	- 20 =	5	x \$9.00	\$45.00
Indep. Claims	4	- 3 =	1	x \$43.00	\$43.00
Multiple Dependent Claims (check if applicable)	<input type="checkbox"/>				\$0.00
				<b>BASIC FEE</b>	<b>\$385.00</b>
OTHER FEE (specify purpose)					\$0.00
				<b>TOTAL FILING FEE</b>	<b>\$473.00</b>

A check in the amount of \$473.00 to cover the filing fee is enclosed.

The Director is hereby authorized to charge and credit Deposit Account No. 07-1180 as described below.

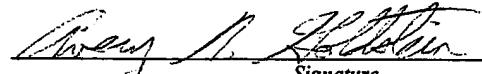
Charge the amount of \_\_\_\_\_ as filing fee.

Credit any overpayment.

Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.

Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

Dated: November 11, 2008

  
\_\_\_\_\_  
Signature

Avery N. Goldstein, Reg. No. 39,204  
Attorney for Applicant  
Gifford, Krass, Groh, Sprinkle,  
Anderson & Citkowski, P.C.  
280 N. Old Woodward Avenue, Suite 400  
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(248) 647-6000

cc:

O I P E  
APR 13 2004  
PATENT & TRADEMARK OFFICE  
APPLICATION DATA SHEET

Electronic Version v14

APR 13 2004

Stylesheet Version v14.0

Title of Invention

METHODS AND COMPOSITIONS OF GENE DELIVERY AGENTS FOR SYSTEMIC AND LOCAL THERAPY

Application Type: regular, utility

Attorney Docket Number: TSR-10002/38

Correspondence address:

Customer Number: 25006 \*25006\*

Continuing Data:

This is a Non-Provisional of US application number 60/425,379, filed 2002-11-12 , now pending.

Inventors Information:

Inventor 1:

Applicant Authority Type: Inventor

Citizenship: US

Given Name: John

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State of Residence: MI

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Inventor 2:

Applicant Authority Type: Inventor  
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Inventor 3:

Applicant Authority Type: Inventor  
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Given Name: Phillip  
Family Name: Kish  
City of Residence: Ann Arbor  
State of Residence: MI  
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City of Mailing Address: Ann Arbor  
State of Mailing Address: MI  
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Country of Mailing Address: US  
Phone:  
Fax:

E-mail:

Attorney Information:

practitioner(s) at Customer Number:

25006 \*25006\*

as our attorney(s) or agent(s) to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith.

Publication Information:

Suggested Figure for Publication -

Suggested Classification -

Suggested Technology Center -

Total Number of Drawing Sheets - 7

TSR-10002/38  
31105gs

METHODS AND COMPOSITIONS OF GENE DELIVERY  
AGENTS FOR SYSTEMIC AND LOCAL THERAPY

RELATED APPLICATION

This application claims priority of United States Provisional Patent  
5 Application Serial No. 60/425,379 filed November 12, 2002, which is  
incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to gene therapy and more particularly to  
drug delivery molecules for delivering various nucleic acid compositions to the  
10 lumen of the intestine or to localized tissues.

BACKGROUND OF THE INVENTION

Gene therapy has garnered considerable attention as a method to treat  
various human diseases by the enhancement of protein production. These  
include gene replacement or gene augmentation.

15 The delivery of genetic material into a multi-celled organism has  
proven more difficult than initially imagined. A variety of techniques have  
been developed to accomplish *in vivo* transformation of cells including direct  
injection of nucleic acid or a particle decorated with nucleic acid directly into  
cells, recombinant viruses, liposomes and receptor mediated endocytosis.

20 In attempting to develop lower cost modes of administration that are  
likely to enhance patient compliance, intestinal gene therapy has been  
recognized as an attractive situs for *in vivo* gene therapy owing to the ease of

access through oral or rectal routes. However, the intestine routinely degrades large quantities of foreign nucleic acid ingested as part of foodstuffs. DNases and RNAses in the intestinal tract represent a significant barrier to the entry of intact and functional nucleic acids to intestinal tract cells.

5       U.S. Patent 6,225,290 represents an effort to deliver bare nucleic acid sequences through laparotomy, oral or suppository administration but is silent as to nucleic acid protection and overcoming the above-stated problems of intestinal administration. It is generally agreed that an oral administration of nucleic acids represents the least expensive and most likely route for the 10 attainment of patient compliance with dosing requirements.

While oral administration is generally recognized as the superior route, little attention has been paid to methodologies and packaging of DNA to preclude intestinal degradation. U.S. Patent 6,500,807 is representative of an attempt to produce a protective coating of carbohydrate around a nucleic acid 15 to facilitate oral administration. It would be advantageous to deliver nucleic acids in a form other than micelles to facilitate conventional pharmaceutical compounding. Thus, there exists a need for gene delivery agents amenable to efficient transfection of target cells capable of inducing systemic and/or local transfection.

20

#### SUMMARY OF THE INVENTION

A method is provided for the packaging of a nucleic acid with a chelating agent having a coordinating moiety linked to a central hydrophobic moiety that terminates in a hydrophilic moiety. The complex is well suited for

oral and other forms of therapeutic administration of nucleic acids in order to exact systemic and/or localized gene delivery therapy. Intestinal epithelial cells, as well as non-epithelial cells within the gastrointestinal tract and other target cells, are transformed for short or long-term therapies through oral 5 administration, direct injection, or infusive administrations. In a preferred embodiment, a nucleic acid conjugating agent contains a bile acid linked with a polycationic peptide.

A nucleic acid conjugating agent particulate composition amenable for administration as a gene therapy composition is provided. The composition is 10 readily adjusted to create a particle having a controlled size and net-zero, -positive, or -negative charge. The resulting composition is optionally provided in a pharmaceutically acceptable carrier for administration to achieve gene therapy, elicit an immunological response, label transfected cells, or deliver associated pharmaceutically active agents therewith.

15

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is transmission electron microscopy (TEM) of a bile acid conjugate (BAC)/plasmid DNA (pDNA) complex;

Figures 2a-2d are relative percent particle size bar graphs of: (Fig. 2a) pDNA; (Fig. 2b) pDNA and 50  $\mu\text{g}/\text{ml}$  BAC initially upon mixing and corresponding to a negatively charged complex; (Fig. 2c) pDNA and 200  $\mu\text{g}/\text{ml}$  BAC initially upon mixing and corresponding to a neutrally charged complex; and (Fig. 2d) the complex depicted in Figure 2c after two hours of 20 mixing;

Figures 3a-3c are relative percent particle size bar graphs of inventive BAC-pDNA particles having a relative ratio of BAC:pDNA of 80,699:1 in: (Fig. 3a) water; (Fig. 3b) simulated intestinal fluid; and (Fig. 3c) simulated gastric fluid;

5       Figure 4 is a plot of the zeta potential measured as a function of conjugating agent:DNA mol ratio where (●) indicates addition of further conjugating agent after particle formation and (▲) indicates the addition of additional nucleic acid after particle formation;

10      Figure 5 is an electrophoretic gel showing the relative mobility of nucleic acid, alone and in combination with at least one of conjugating agent, polyaspartic acid and DNase I;

Figure 6 is a bar graph showing *in vitro* transfection of Hela cells with BAC-luciferase pDNA at various conjugating agent:pDNA ratios; and

15      Figure 7 is a plot of inventive complex single pass absorption for neutrally charged and positively charged radiolabeled BAC-pDNA as a function of time where filled symbols indicate jejunal absorption and open symbols indicate ileal absorption.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention has utility as a treatment for a variety of disease conditions or deficiencies. These conditions and deficiencies illustratively include: enzyme deficiency, erythropoietin, catalase, endotoxic shock/sepsis, adenosine deaminase for treatment of severe combined immunodeficiency, lipid-binding protein (LBP), purine nucleotide phosphorylase, galactosidase,

beta-glucuronidase, antioxidants for cancer, therapy anemia, superoxide dismutase, cancer, growth factors for use in wound healing, induction of red blood cell formation and the like,  $\alpha$ -interferon,  $\beta$ -interferon, epidermal growth factor, granulocyte colony stimulating factor (G-CSF), alpha-IL1, gamma-interferon, phenylalanine ammonia lyase, transforming growth factor, arginase, erythropoietin, L-asparaginase, thrombopoietin, uricase, insulin-like growth factor-1, insulin, human growth hormone, monoclonal antibodies, tissue necrosis factor, cardiovascular disease, diabetes, tissue plasminogen activator, urokinase (native or chimeric), glucagon,  $\alpha_1$ -antitrypsin, -insulinotrophic hormone, clotting disorders, antithrombin-III, other proteases or protease inhibitors, clotting factor VIII, apolipoproteins (particularly B-48), circulating scavenger receptor, APO A1 which converts low-density lipoproteins to high-density lipoproteins, gastrointestinal and pancreatic deficiencies, obesity and feeding, pepsin (for esophageal reflux), Ob gene product, cholecystokinin (CCK), trypsin, chymotrypsin, bone diseases, elastase, carboxypeptidase, calcitonin, lactase (for lactose deficiency), PTH-like hormone, sucrase, intrinsic factor (pernicious anemia), myasthenia gravis (acetylcholine receptors), Graves' disease (thyroid-stimulating hormone receptor), organ-specific autoimmune diseases (target of antibody in parentheses), thyroiditis (thyroid, peroxidase), insulin-resistant diabetes with acanthosis nigricans or with ataxia telangiectasia (insulin receptor), allergic rhinitis, asthma ( $\beta_2$ -adrenergic receptors), juvenile insulin-dependent diabetes (insulin, GAD65), pernicious anemia (gastric parietal cells, vitamin B<sub>12</sub> binding site of intrinsic

factor), Addison's disease (adrenal cells), idiopathic hypoparathyroidism (parathyroid cells), spontaneous infertility (sperm), premature ovarian failure (interstitial cells, corpus luteum cells), pemphigus (intercellular substance of skin and mucosa), bullous pemphigoid (basement membrane zone of skin and mucosa), primary biliary cirrhosis (mitochondria), autoimmune hemolytic anemia (erythrocytes), idiopathic thrombocytopenic purpura (platelet), idiopathic neutropenia (neutrophils), vitiligo (melanocytes), osteosclerosis and Meniere's disease (type II collagen), chronic active hepatitis (nuclei of hepatocytes), systemic autoimmune diseases (defect/organ affected in parentheses), Goodpasture's syndrome (basement membranes), rheumatoid arthritis ( $\gamma$ -globulin, EBV-related antigens, collagen types II and III), Sjogren's syndrome ( $\gamma$ -globulin, SS-A (Ro), SS-B (La), systemic lupus erythematosus (nuclei, double-stranded DNA, single-stranded DNA, Sm ribonucleoprotein, lymphocytes, erythrocytes, neurons, gamma-globulin), scleroderm (nuclei, Scl-70, SS-A (Ro), SS-B (La), centromere, polymyositis (nuclei, Jo-1, PL-7, histadyl-tRNA synthetase, threonyl-tRNA synthetase, PM-1, Mi-2), rheumatic fever (myocardium heart valves), and choroid plexus.

The invention involves methods and products for oral, parenteral, mucosal, and infusion delivery of nucleic acid for both systemic and localized therapy. Depending on the nature of the nucleic acid sequence, these contain, in non-covalently bound form, one or more substances having an affinity for nucleic acid, which are capable of increasing the efficiency of absorption of the complexes into the cells. Cells of a mammalian subject, either intestinal

epithelia after oral delivery, or cells in other organs after other forms of inventive delivery, are altered to operatively incorporate a gene which expresses a protein, which is secreted directly into the organ and/or blood stream to provide a therapeutic effect. The use of naked nucleic acid protected by complexation with adsorption and/or internalization factors avoids the complications associated with use of viral vectors to accomplish gene therapy.

An inventive complex is delivered via the intestinal lumen in a variety of ways, including through timed-release capsules, such as those detailed in U.S. Patent 4,976,949, thereby obtaining a simple, noninvasive method of gene delivery.

These complexes also optionally are delivered to other organs of the body in a variety of ways, including direct injection or infusion.

As used herein, a "gene" is defined to be an isolated nucleic acid molecule of greater than twenty nucleotides. A gene operative herein is recognized to be one that illustratively replaces or supplements a desired function, or achieves a desired effect such as the inhibition of tumor growth or induction of an immune response to the gene itself or a polypeptide transcribed therefrom. It is appreciated that a nucleic acid molecule according to the present invention illustratively includes plasmids, vectors, external guide sequences for RNAase, ribozymes, DNA, RNA, and miRNA. Antisense nucleic acids sequences are also administered according to the present invention. A gene is generally under the control of an appropriate promoter, which may be inducible, repressible, or constitutive. Promoters can be general promoters, yielding expression in a variety of mammalian cells, or cell specific,

or even nuclear versus cytoplasmic specific. Viral promoters such as CMV are also operative herein. These are known to those skilled in the art and can be constructed using standard molecular biology protocols.

In a preferred embodiment administration is oral and targeted to  
5 transfect intestinal epithelial cells.

As used herein, a "subject" includes humans, non-human primates, horses, goats, cows, sheep, pigs, dogs, cats, and rodents. The methods and compounds of the present invention are administered in therapeutically effective amounts.

10 As used herein, a "therapeutically effective amount" is defined to include an amount necessary to delay the onset of, inhibit the progress of, relieve the symptoms of, or reverse a condition being treated; induce an immune response to the delivered gene or a polypeptide encoded thereby or regulate the expression of an existing cellular product. The therapeutically 15 effective amount is one that is less than that that produces medically unacceptable side effects. It is appreciated that a therapeutically effective amount varies with a number of factors illustratively including subject age, condition, sex and the nature of the condition being treated. It is further appreciated that determining a therapeutically effective dose is within the 20 knowledge of one of ordinary skill in the art.

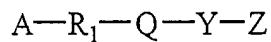
As used herein, however, the term "peptide" is intended to include mimetics and is used synonymously with polypeptide. The term "amino acid" is intended to include D-form amino acids and modified amino acids.

The compounds of the present invention are administered to a subject at dosage levels in the range of about  $0.000002\text{ mg/m}^2$  to about  $4\text{ mg/m}^2$  of conjugating agent combined with about  $0.2\text{ mg/m}^2$  to about  $4\text{ mg/m}^2$  of nucleic acid per day. For a normal human adult having a body weight of about 70 kg,

5 a dosage in the range of about  $0.005\text{-}10\text{ mg/kg/day}$  conjugating agent combined with about  $5\times 10^{-6}\text{-}10\text{ mg/kg/day}$  nucleic acid is preferable. The general ratio of the amount of conjugating agent to the nucleic acid ranges from about 50:1-500,000:1 in the composition which is administered to a subject.

After oral delivery the transformed intestinal epithelial cells provide short or long term therapies for diseases associated with a deficiency in a particular protein or which are amenable to treatment or palliation by over expression of a protein including metabolic disorders, endocrine disorders, circulatory disorders, coagulation disorders, cancer, and gastrointestinal disease.

15 An inventive conjugating agent has the general formula:



where  $\text{A}-\text{R}_1$  is a cholesterol derivative; a  $\text{C}_8\text{-C}_{24}$  alkyl;  $\text{C}_8\text{-C}_{24}$  heteroatom substituted alkyl wherein the heteroatom is O, N or S; where A is a hydrophilic moiety A that illustratively includes  $\text{C}_0\text{-C}_4$  alkyl-hydroxy, -substituted amino, -quaternary amino, -sulfonate, -phosphonate, and -carboxylate; and targeting ligand; where the targeting ligand includes amino acids, hormones, antibodies, cell adhesion molecules, folate, polypeptides, vitamins, saccharides, transferring, drugs, and neurotransmitters; where Q is

sulfur, a secondary amine, or oxygen; where Y is a linker peptide having a negative, neutral, or positive charge; and where Z is a polyionic peptide. Specific examples of inventive cholesterol derivatives illustratively include cholestanol, coprostanol, cholic acid, glycocholic acid, chenodeoxycholic acid, 5 desoxycholic acid, glycochenodeoxycholic acid, taurocholic acid, and taurochenodeoxycholic acid. Specific examples of C<sub>8</sub>-C<sub>24</sub> alkyls are 13-hydroxyl tridecanoic acid; 1,12 dodecane diol; and 1,12 dodecanediame.

A peptide linker sequence Y is preferably employed to separate A-R<sub>1</sub>-Q and the polyionic peptide sequence Z that interacts with the nucleic acid by a 10 distance sufficient to ensure that the cholesterol derivative is stearically accessible and that the polyionic peptide Z folds into its secondary and tertiary structures. Such a peptide linker sequence Y is incorporated into an inventive compound using standard techniques well known in the art. Suitable peptide linker sequences Y are chosen based on the following factors: (1) their ability 15 to adopt a flexible extended conformation; (2) their inability to adopt a secondary structure that could interact with functional epitopes of the inventive compound; and (3) the lack of hydrophobic or charged residues that might react with the polyionic peptide functional epitopes. Preferred peptide linker sequences contain Gly, Asn and Ser residues. Other near-neutral amino acids, 20 such as Thr and Ala, also are operative in the linker sequence. Amino acid sequences which may be usefully employed as linkers include those disclosed in Maratea et al., Gene 40:39-46, 1985; Murphy et al., Proc. Natl. Acad. Sci. USA 83:8258-8262, 1986; U.S. Patent Nos. 4,935,233 and 4,751,180. The

linker sequence may be from 0 to about 50 amino acids in length. A peptide linker sequence Y is not required when the polyionic peptide Z has non-essential N-terminal amino acid regions that can be used to separate the functional domains and prevent steric interference.

5       A polyionic peptide Z according to the present invention is generally a highly charged polypeptide or protein, having an isoelectric point of between about 3 to about 12. The polyionic peptide Z is generally soluble in salt-free, aqueous solution. Illustrative polyionic peptides include, but are not limited to, one or more of the following: albumin, such as from egg or animal, e.g. 10 bovine, serum; derivatized collagen polypeptides, such as cationic collagen polypeptides; elastin; globulin polypeptide, such as myoglobin; synthetic polypeptides rich in glutamic acid, aspartic acid, lysine or arginine residues, such as polyaspartic acid; and derivatives of such proteinaceous or other materials, such as keratin. A particularly preferred polyionic peptide Z is 15 polyaspartic acid. It is appreciated that in the formation of synthetic polyionic peptides that the inclusion of both cationic and anionic amino acid residues create a complex charge on an inventive compound under pH conditions that vary from the isoelectric point.

Proteins usefully expressed according to the administration of the 20 present invention illustratively include proteases, pituitary hormones, protease inhibitors, growth factors, cytokines, somatomedians, chemokines, immunoglobulins, gonadotrophins, interleukins, chemotactins, interferons, and lipid-binding proteins, specific examples of which illustratively include insulin,

interferon- $\alpha$ 2B, human growth hormone (hGH), transforming growth factor (TGF), erythropoietin (EPO), ciliary neurite transforming factor (CNTF), clotting factor VIII, insulin-like growth factor-1 (IGF-1), bovine growth hormone (BGH), granulocyte macrophage colony stimulating factor (GM-CSF), platelet derived growth factor (PDGF), interferon- $\alpha$ 2A, clotting factor VIII, brain-derived neurite factor (BDNF), thrombopoietin (TPO), insulintropin, tissue plasminogen activator (tPA), IL-1, IL-2, urokinase, IL-1 RA, streptokinase, superoxide dismutase (SOD), adenosine deamidase, catalase, calcitonin, arginase, fibroblast growth factor (FGF) (acidic or basic), neurite growth factor (NGF), phenylalanine ammonia lyase, granulocyte colony stimulating  $\gamma$ -interferon factor (G-CSF), L-asparaginase, pepsin, uricase, trypsin, chymotrypsin, elastase, carboxypeptidase, lactase, sucrase, intrinsic factor parathyroid hormone (PTH)-like hormone, calcitonin, Ob gene product, cholecystokinin (CCK), glucagon, glucagon-like-peptide I (GLP-1), and insulinotropic hormone.

The conjugate agent A-R<sub>1</sub>-Q-Y-Z is preferably a bile acid conjugated with a polycationic peptide linked to the bile acid steroid backbone. The bile acid moiety acts to target the conjugate to bile acid transporters in the lumen of the intestine and assist in the cellular internalization of the complex. Short polycation peptides rich in arginine or lysine, such as a six amino acid residue or longer chain, provide multiple functions illustratively including: a) having an affinity for nucleic acid, b) act condensing agent, c) protect the nucleic acid from nuclease activity and d) assist in cellular internalization of the complex.

Conjugation of the polyionic polypeptide chain to the bile salt is made through the hydroxyl groups in the 3, 7, or 12 positions of a bile acid steroid nucleus, or on the 24-carboxyl group of the bile acids.

Composition of the polyionic peptide nucleic acid condensing moiety is  
5 altered to vary the affinity to the nucleic acid, providing changes in the rate of intracellular decondensing of the nucleic acid. These alterations are known to one skilled in the art.

Alternatively, A is a targeting ligand. A targeting ligand according to the present invention is any molecule which binds to specific types of cells. A  
10 targeting ligand may be any type of molecule having a corresponding cellular receptor. Ideally, a targeting ligand is recognized by a cellular receptor and expressed only on a specific type of cell thereby affording selectivity. Examples of targeting ligands which are operative herein include amino acids, hormones, antibodies, cell adhesion molecules, folate, polypeptides, vitamins,  
15 saccharides, transferring, drugs, and neurotransmitters. The 12-residue membrane-translocating peptide (Ala-Ala-Val-Leu-Leu-Pro-Val-Leu-Leu-Ala-Ala-Pro) (SEQ ID NO: 1) is exemplary of a target ligand form of R<sub>1</sub>. The targeting ligand operative to either target, increase adsorption, internalization or nuclear localization of the inventive compound.

20 In another embodiment, the selected nucleic acid is, or encodes, an RNA molecule comprising an antisense which blocks expression of a gene, e.g., in a tumor cell. By blocking expression of this selected gene, inhibition of growth is observed for the tumor.

It is appreciated that a nucleic acid delivered according to the present invention includes a ribozyme. A ribozyme is a catalytic RNA molecule that cleaves other RNA molecules such as mRNA transcripts in a cell. Common targets include RNAs having GUC or GUA subsequences. For example, 5 hairpin ribozymes typically cleave one of two target sequences. GUC hairpin ribozymes cleave an RNA target sequence consisting of NNNBCN\*G UCNNNNNNNN (SEQ ID NO: 2) where N\*G is the cleavage site, B is any of G, U or C, and where N is any of G, U, C, or A. GUA ribozymes typically cleave an RNA target sequence consisting of NNNNN\*GUANNNNNNNN (SEQ ID NO: 3) where N\*G is the cleavage site and where N is any of G, U, C, 10 or A. See, De Young et al. (1995) Biochemistry 34: 15785-15791. Ribozymes delivered optionally have non-standard ribonucleotide bases, or deoxyribonucleotide bases, which can stabilize the ribozyme and make the ribozyme resistant to RNase enzymes. Alternatively, the ribozyme is modified 15 to a phosphothio analog, thereby rendering the ribozyme resistant to endonuclease activity.

According to the present invention, a systemic effect is achieved by transducing cells with genes that express proteins that are secreted into the circulatory system and therefore provide a systemic effect. As is known to one skilled in the art, deleting from a gene pro-protein sequences or transporter sequences tends to restrict a protein to an intracellular effect. Additionally, 20 according to the present invention gene expression and therefore therapeutic effect is regulated through administration. In an embodiment where intestinal

epithelial cells are transduced, these cells are sloughed from the lumen every several days thereby affording only transient gene expression. Conversely, the transduction of cells with less turnover than intestinal epithelial cells affords longer gene expression periods.

5       The compounds of the present invention can be administered to a patient either alone or a part of a pharmaceutical composition. The compositions can be administered to patients either orally, rectally, parenterally (intravenously, intramuscularly, or subcutaneously), intracisternally, intravaginally, intreperitoneally, intravesically, locally (powders, ointments, or drops), or as a buccal or nasal spray.

10      Compositions suitable for parenteral injection may comprise physiologically acceptable sterile aqueous or nonaqueous solutions, dispersions, suspensions or emulsions, and sterile powders for reconstitution into sterile injectable solutions or dispersions. Examples of suitable aqueous and nonaqueous carriers, diluents, solvents or vehicles include water, ethanol, polyols (propyleneglycol, polyethyleneglycol, glycerol, and the like), suitable mixtures thereof, vegetable oils (such as olive oil) and injectable organic esters such as ethyl oleate. Proper fluidity can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in 15     the case of dispersions and by the use of surfactants.

20      These compositions may also contain adjuvants such as preserving, wetting, emulsifying, and dispensing agents. Prevention of the action of microorganisms can be ensured by various antibacterial and antifungal agents,

for example, parabens, chlorobutanol, phenol, sorbic acid, and the like. It may also be desirable to include isotonic agents, for example, sugars, sodium chloride, and the like. Prolonged absorption of the injectable pharmaceutical form can be brought about by the use of agents delaying absorption, for 5 example, aluminum monostearate and gelatin.

Solid dosage forms for oral administration include capsules, tablets, pills, powders, and granules. In such solid dosage forms, the active compound is admixed with at least one inert customary excipient (or carrier) such as sodium citrate or dicalcium phosphate or (a) fillers or extenders, as for 10 example, starches, lactose, sucrose, glucose, mannitol, and silicic acid, (b) binders, as for example, carboxymethylcellulose, alginates, gelatin, polyvinylpyrrolidone, sucrose, and acacia, (c) humectants, as for example, glycerol, (d) disintegrating agents, as for example, agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain complex silicates, and 15 sodium carbonate, (e) solution retarders, as for example, paraffin, (f) absorption accelerators, as for example, quaternary ammonium compounds, (g) wetting agents, as for example, cetyl alcohol, and glycerol monostearate, (h) adsorbents, as for example, kaolin and bentonite, and (i) lubricants, as for example, talc, calcium stearate, magnesium stearate, solid polyethylene 20 glycols, sodium lauryl sulfate, or mixtures thereof. In the case of capsules, tablets, and pills, the dosage forms may also comprise buffering agents.

Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugar as well as high molecular weight polyethyleneglycols, and the like.

Solid dosage forms such as tablets, dragees, capsules, pills, and  
5 granules can be prepared with coatings and shells, such as enteric coatings and others well known in the art. They may contain opacifying agents, and can also be of such composition that they release the active compound or compounds in a certain part of the intestinal tract in a delayed manner.  
Examples of embedding compositions which can be used are polymeric  
10 substances and waxes. The active compounds can also be in micro-encapsulated form, if appropriate, with one or more of the above-mentioned excipients.

Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, solutions, suspensions, syrups, and elixirs. In addition to  
15 the active compounds, the liquid dosage forms may contain inert diluents commonly used in the art, such as water or other solvents, solubilizing agents and emulsifiers, as for example, ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl alcohol, benzyl benzoate, propyleneglycol, 1,3-butyleneglycol, dimethylformamide, oils, in particular,  
20 cottonseed oil, groundnut oil, corn germ oil, olive oil, castor oil and sesame oil, glycerol, tetrahydrofurfuryl alcohol, polyethyleneglycols and fatty acid esters of sorbitan or mixtures of these substances, and the like.

Besides such inert diluents, the composition can also include adjuvants, such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, and perfuming agents.

Susensions, in addition to the active compounds, may contain  
5 suspending agents, as for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, or mixtures of these substances, and the like.

Compositions for rectal administrations are preferably suppositories  
10 which can be prepared by mixing the compounds of the present invention with suitable non-irritating excipients or carriers such as cocoa butter, polyethyleneglycol or a suppository wax, which are solid at ordinary temperatures but liquid at body temperature and therefore melt in the rectum or vaginal cavity and release the active component.

15 Dosage forms for topical administration of a compound of this invention include ointments, powders, sprays, and inhalants. The active component is admixed under sterile conditions with a physiologically acceptable carrier and preservatives, buffers, or propellants as may be required. Ophthalmic formulations, eye ointments, powders, and solution are also  
20 contemplated as being within the scope of this invention.

An inventive compound is also delivered in conjunction with an active therapeutic compound, a pharmaceutically acceptable salt, ester, amide or prodrug. The therapeutic compound illustratively being active as antibiotic, a

gamma or beta radiation emitting species, an anti-inflammatory, an antitumoral, an antiviral, an antibody, a hormone, an enzyme, and antigenic peptide or protein.

The term "pharmaceutically acceptable salts, esters, amides, and prodrugs" as used herein refers to those carboxylate salts, amino acid addition salts, esters, amides, and prodrugs of the compounds of the present invention which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of patients without undue toxicity, irritation, allergic response, and the like, commensurate with a reasonable benefit/risk ratio, and effective for their intended use, as well as the zwitterionic forms, where possible, of the compounds of the invention. The term "salts" refers to the relatively non-toxic, inorganic and organic acid addition salts of compounds of the present invention. These salts can be prepared in situ during the final isolation and purification of the compounds or by separately reacting the purified compound in its free base form with a suitable organic or inorganic acid and isolating the salt thus formed. Representative salts include the hydrobromide, hydrochloride, sulfate, bisulfate, nitrate, acetate, oxalate, valerate, oleate, palmitate, stearate, laurate, borate, benzoate, lactate, phosphate, tosylate, citrate, maleate, fumarate, succinate, tartrate, naphthylate mesylate, glucoheptonate, lactobionate and laurylsulphonate salts, and the like. These may include cations based on the alkali and alkaline earth metals, such as sodium, lithium, potassium, calcium, magnesium, and the like, as well as non-toxic ammonium, quaternary ammonium and amine cations including, but

not limited to ammonium, tetramethylammonium, tetraethylammonium, methylamine, dimethylamine, trimethylamine, triethylamine, ethylamine, and the like. (See, for example, S.M. Barge et al., "Pharmaceutical Salts," *J. Pharm. Sci.*, 1977, 66:1-19 which is incorporated herein by reference.)

5       The examples presented below are intended to illustrate particular embodiments of the invention and are not intended to limit the scope of the specification, including the claims.

## EXAMPLES

### Example 1

#### 10      **Method for synthesis of bile acid conjugates (BAC)**

BAC is synthesized by solid phase chemistry on a peptide synthesizer. A six L-arginine peptide is first synthesized on the resin bed using standard 9-fluorenylmethoxycarbonyl (FMOC) chemistry. To attach the bile acid salt, an excess of chendoxycholic acid is added to the resin and allowed to react 15 with the immobilized peptide. After conjugation, BAC is cleaved from the resin and purified to greater than 95% purity by HPLC.

### Example 2

#### **Construction of Expression Plasmids**

An expression plasmid using an optimized Cytomegalovirus (CMV) 20 early promoter-enhancer to drive transgene expression (pCF1) is utilized. For cell localization and transfection expression experiments the firefly luciferase cDNA is used as a reporter transgene (pCF1-luc). Plasmid backbones which are chosen to contain the origin of replication and an antibiotic resistance gene

or other selectable marker allowing the growth and maintenance of the plasmid in its bacterial host. Other attributes to facilitate the production of plasmid DNA are: 1) the ability of the plasmid to produce high copy number in the host bacteria; 2) a eukaryotic transcriptional promoter to initiate the synthesis of mRNA when it enters the target cells; 3) the DNA coding sequence encoding the protein of interest with a translational start codon (ATG) in the sequence for initiation of protein synthesis and a stop codon to terminate translation; and 5 4) an optional transcription termination sequence.

### Example 3

#### 10 Preparation of BAC/pDNA Complexes

Typically an equal volume of BAC solution at 3 mg/ml (2.25 mM) is slowly added with mixing to a pDNA solution at a concentration of 250 $\mu$ g/ml to form a neutrally charged complex. Mass spec analysis has provided evidence that the major ionic species in the BAC has a charge of +3 per BAC 15 molecule (MW = 1329) under neutral conditions (data not shown). Assuming a charge of -2 per base pair of the 4550 bp pDNA (MW = 3,003,000) (total DNA charge = -9100), a net neutral charge would theoretically require a ratio of about 3033:1 (BAC:pDNA). Physical measurements of the BAC/pDNA complex appear require about 10-fold more BAC to neutralize the pDNA 20 charge (see Table 1). The presence of buffer salts bound to the BAC during synthesis and purification may partially explain this observation.

**Table 1**

BAC amount μg/ml	BAC:pDNA molar ratio	Particle Charge determined by Zeta Potential
50	8070:1	Negative
200	32,280:1	Neutral
2000	322,799:1	Positive

**Example 4**

**BAC condenses plasmid DNA.**

The ability of BAC to condense DNA is determined using transmission electron microscopy (TEM). TEM of a BAC/pDNA particle complex is shown in Figure 1. The mole ratio of BAC:pDNA is 1581:1, which retained a net negative charge on the particle. The samples after mixing are diluted in water, and a drop applied to the carbon-coated formvar-film grid. The samples are dried and stained with uranyl acetate before viewing. Length bars in Figure 1 are 100 nM long. Even at this low molar ratio of BAC:pDNA clear rod shaped particles (toroids) are formed.

**Example 5**

**BAC condensed plasmid DNA forms discrete particles.**

NICOMP particle size analysis is shown in Figure 2. 1 ml of 14 μg/ml DNA plasmid is mixed with 1 ml of BAC at the concentrations shown in Table 1. Also shown in Table 1 are the calculated molar ratios and particle charges.

Particle sizes are measured at a specific time after mixing of the pDNA with the BAC.

Figures 2(a)-(d) show some representative results of these experiments. Mixtures of pDNA and BAC start forming particles immediately. However, with increasing time these particles appear to aggregate, so that at later times particles larger than 1  $\mu\text{m}$  are observed. Figure 2(a) is particle sizing for the 5 plasma DNA of Example 2. Figure 2(b) shows the particle size distribution of 1 ml of 14 microgram per ml DNA plasmid mixed with 1 ml of 50 microgram per ml BAC to yield a negatively charged complex which is sized immediately upon mixing. Figure 2(c) shows a particle size distribution as per Figure 2(b) except 200 microgram per ml BAC is introduced instead of 50 microgram per 10 ml BAC to yield a neutrally charged complex. Figure 2(d) shows the particle size distribution for the experiment according to Figure 2(c) two hours after mixing.

#### Example 6

15 **BAC condensed plasmid DNA particle size in simulated gastric or intestinal fluid.**

The behavior of the pDNA/BAC complex in buffers with different pHs to simulate gastric fluid (SGF) or intestinal fluid (SIF) are evaluated. pDNA and BAC (BAC:pDNA: = 80,699:1, slightly positive charge) are mixed first in water and then mixed with the same volume of simulated gastric fluid (SGF, 20 0.1 M HCl, pH 1.2) or simulated intestinal fluid (SIF, 0.05 M phosphate buffer, pH 6.8). Measurements are made after two hours incubation at 37°C. After 2 hours, most of the DNA complexes in water (Figure 3a) and SIF (Figure 3b) are observed to be greater than 1  $\mu\text{m}$  in size. However, over 30% of DNA complex incubated in SGF (Figure 3c) is observed to be under 1  $\mu\text{m}$  size.

These results indicate that pH has some effect on the physical behavior of BAC/pDNA complexes.

**Example 7**

Measurement of the zeta potential (net charge) of the particle complexes are made after mixing BAC/pDNA in water. 800  $\mu$ l of 11.07 microgram/ml DNA plasmid is mixed with 800  $\mu$ l of 50  $\mu$ g/ml BAC (DNA:BAC = 1:10,205 -negatively charged). 10  $\mu$ l of 500  $\mu$ g/ml or 1 mg/ml BAC is added and zeta potential is remeasured in the first experiment ( $\bullet$ ). 200 microliters of 10 micrograms/ml pDNA is prepared and 2 microliters of 3 mg/ml BAC is added before zeta potential remeasurement in the second 10 experiment ( $\pi$ ). Additional aliquots of BAC are added and the zeta potential remeasured (Figure 4).

**Example 8**

**DNase protection assays** - The ability for BAC complex formation to protect DNA from endonuclease activity is examined. We have utilized the 15 ability of polyanions such as polyaspartic acid (PAA) to competitively dissociate the polycations from DNA. Katayose S, Kataoka K. *Water-soluble polyion complex associates of DNA and poly(ethylene glycol)-poly(L-lysine) block copolymer*. Bioconjug Chem 1997;8:702-7.

- 1) The mixture of luciferase BAC/pDNA is stored at room temperature for 2.5 20 hours (BAC/pDNA: = 9038:1).
- 2) 10  $\mu$ l of 10 mg/ml PAA or milli-Q water is added to each sample (5  $\mu$ l of DNA complex mixture) and stored at room temperature for 2 hours.

3) The molar ratio is (DNA:BAC:PAA= 1:9038:13,572), the charge ratio (DNA:BAC:PAA=1:3:388), assuming BAC has 3 positive charges and PAA has 260 negative charges.

4) 5 ul of 100 kunit/ml DNaseI or milli-Q water is added to each sample and those samples are incubated at 37°C for 15 min and heated at 70°C for 15 min.

5) 2 ul of 500 mM EDTA and 1 ul of 5% SDS is added to each sample and heated at 55°C for 3 hours to dissociate the BAC from the pDNA. Samples are then electrophoresed in an agarose gel and stained with ethidium bromide (Figure 5).

Extremely harsh conditions are required to dissociate BAC from the BAC/pDNA complex (1% SDS at 55°C for 2 hours). One hour is not enough to reach a plateau dissociation level.

DNaseI together with BAC in the mixture altered the effect the dissociation by SDS (Figure 5, Lane 2). The DNA sample which is incubated at 37°C for 15 min with DNaseI showed almost complete fragmentation (Figure 5, Lane 3). The BAC/pDNA sample incubated in the presence of PAA and DNaseI showed less intact DNA banding (Figure 5, Lane 1) than BAC/pDNA samples with or without treatment with PAA (Figure 5, Lanes 4 and 5 respectively).

#### Example 9

**In Vitro Transfection Assays:** To examine the capability of the BAC/pDNA complexes to transfect cells *in vitro*, the ability of BAC to

transfect Hela tissue cultures using the firefly luciferase gene is examined. In transient transfection assays (24 h), BAC enhanced the transfection efficiency in combination with liposomes (data not shown). In accordance with the present invention, BAC/pDNA is able to transfect Hela cells alone as a single agent (Figure 6). The charge ratio is approximately neutral. The approximate molar ratios are indicated in parenthesis.

**Example 10**

***In Situ* Intestinal Absorption:** In order to examine the capability of the BAC/pDNA complex to bind and/or be absorbed onto the intestinal lumen cells the absorption of nicked-radiolabeled pDNA in a single pass perfusion experiment is tested. Using isolated ileal or jejunal segments radio-labeled BAC/pDNA mixtures mixture is mixed with HEPES buffer, pH 7.4, and perfused at jejunal (filled symbols) and ileal (open symbols) sites. After 30 min of steady state, sample fractions are collected and the absorbed fraction of BAC/pDNA calculated. BAC/pDNA mixtures used are pDNA:BAC 1:27,000 neutrally charged and 1:54,000 positively charged. Uncomplexed pDNA is used as a control.

Between 20-40% of the “neutrally charged” BAC/pDNA complex is absorbed in a single pass of the intestine as shown in Figure 7. As a result, it is appreciated that this complex should be completely absorbed after oral dosing.

**Example 11**

***In Situ* Intestinal Absorption for Translocating Peptide BAC:** The 12-residue membrane translocating peptide (SEQ ID NO: 1) is coupled to the

BAC by way of a condensation reaction involving the three alpha hydroxyl group. The complexes as detailed in Example 10 are recreated with the membrane translocating BAC yielding comparable results to those depicted in Figure 7.

5      **Example 12**

*In Situ* Intestinal Absorption for Translocating Peptide BAC: The 12-residue membrane translocating peptide (SEQ ID NO: 1) is coupled to the BAC by way of a condensation reaction involving the three alpha hydroxyl group. The complexes as detailed in Example 10 are recreated with the 10 membrane translocating BAC yielding comparable results to those depicted in Figure 7.

Patent applications and publications mentioned in the specification are indicative of the levels of those skilled in the art to which the invention pertains. These applications and publications are incorporated herein by 15 reference to the same extent as if each individual application or publication was specifically and individually incorporated herein by reference.

The foregoing description is illustrative of particular embodiments of the invention, but is not meant to be a limitation upon the practice thereof. The following claims, including all equivalents thereof, are intended to define the 20 scope of the invention.

What is claimed is:

CLAIMS

1        1. A method for treating a disease condition or deficiency through  
2        gene delivery to target cells of a subject comprising the step of administering a  
3        conjugating agent-nucleic acid complex where the conjugating agent comprises  
4        R<sub>1</sub>-Z, where R<sub>1</sub> is a cholesterol derivative; a C<sub>8</sub>-C<sub>24</sub> alkyl; C<sub>8</sub>-C<sub>24</sub> heteroatom  
5        substituted alkyl wherein the heteroatom is O, N, or S; or membrane importer  
6        and transporter proteins and Z is a polyionic peptide.

1        2. The method of claim 1, wherein said administration is oral.

1        3. The method of claim 1, wherein nucleic acid of said complex is  
2        expressed as a protein in said target cells.

1        4. The method of claim 3 wherein said protein is secreted from  
2        said target cells.

1        5. The method of claim 3 wherein said protein is of a class selected  
2        from the group consisting of: proteases, pituitary hormones, protease  
3        inhibitors, growth factors, cytokines, somatomedians, chemokines,  
4        immunoglobulins, gonadotrophins, interleukins, chemotactins, interferons, and  
5        lipid-binding proteins.

1           6. The method of claim 1 wherein said nucleic acid of said  
2 complex is selected from the group consisting of: DNA, RNA, mRNA,  
3 miRNA, ribozyme, RNase, and antisense sequences.

1           7. The method of claim 1 wherein said complex is administered as  
2 part of a pharmaceutical composition.

1           8. The method of claim 7 wherein said pharmaceutical  
2 composition comprises an active therapeutic compound.

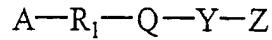
1           9. The method of claim 8 wherein said therapeutic agent is  
2 selected from the group consisting of: an antibiotic, a gamma or beta radiation  
3 emitting species, an anti-inflammatory, an antitumoral, an antiviral, an  
4 antibody, a hormone, an enzyme, antigenic peptide and antigenic protein.

1           10. The method of claim 1 wherein R<sub>1</sub> is a cholesterol derivative.

1           11. The method of claim 10 wherein said cholesterol derivative is  
2 attached to a hydrophilic moiety A.

1           12. The method of claim 1, wherein said target cells are  
2 gastrointestinal cells.

1           13. A gene delivery composition comprising a conjugating agent-  
2         nucleic acid complex having the formula:



4         where A—R<sub>1</sub> is a cholesterol derivative; a C<sub>8</sub>-C<sub>24</sub> alkyl; C<sub>8</sub>-C<sub>24</sub> heteroatom  
5         substituted alkyl wherein the heteroatom is O, N or S; where A is a hydrophilic  
6         moiety A that illustratively includes C<sub>0</sub>-C<sub>4</sub> alkyl-hydroxy, -substituted amino, -  
7         quaternary amino, -sulfonate, -phosphonate, and -carboxylate and a target  
8         ligand; where Q is sulfur, nitrogen, or oxygen; where Y is a linker peptide  
9         having a negative, neutral, or positive charge; and where Z is a polyionic  
10       peptide.

1           14. The composition of claim 13 wherein said cholesterol derivative  
2         is selected from the group consisting of: cholestanol, coprostanol, cholic acid,  
3         glycocholic acid, chenodeoxycholic acid, desoxycholic acid,  
4         glycochenodeoxycholic acid, taurocholic acid, and taurochenodeoxycholic  
5         acid.

1           15. The composition of claim 13 wherein said cholesterol derivative  
2         is a cholic acid or a deoxycholic acid.

1           16. The composition of claim 13 wherein said A derivative is  
2         hydroxyl.

1           17. The composition of claim 13 wherein said Q derivative is  
2       oxygen.

1           18. The composition of claim 13 wherein Y and Z together yield a  
2       net neutral charge.

1           19. The composition of claim 13 wherein Z is polycationic.

1           20. The composition of claim 19 wherein Z contains at least six  
2       residues, each residue independently selected from the group consisting of:  
3       arginine, lysine, an amino acid having a pendent amine group, and a beta  
4       amino acid having a pendent amine group.

1           21. The composition of claim 13 wherein Z is polyanionic.

1           22. The composition of claim 21 wherein Z contains at least six  
2       residues, each residue independently selected from the group consisting of:  
3       aspartic acid, glutamic acid, an amino acid having a pendent carbonyl group,  
4       and a beta amino acid having a pendent carbonyl group.

1           23. Use of a bile acid salt as a conjugating agent to administer  
2       nucleic acid to a subject.

1           24.     The use of claim 23 wherein administration is oral.

1           25.     A commercial package comprising a composition of Formula I  
2     according to claim 1 as an active ingredient together with instructions for the  
3     use thereof as a gene delivery agent to a subject.

## ABSTRACT OF THE DISCLOSURE

A method is provided for the packaging of a nucleic acid with a chelating agent having a coordinating moiety linked to a central hydrophobic moiety that terminates in a hydrophilic moiety. The complex is well suited for oral and other forms of therapeutic administration of nucleic acids in order to exact systemic and/or localized gene delivery therapy. Intestinal epithelial cells, as well as non-epithelial cells within the gastrointestinal tract and other target cells, are transformed for short or long-term therapies through oral administration, direct injection, or infusive administrations. A nucleic acid conjugating agent particulate composition amenable for administration as a gene therapy composition is provided. The composition is readily adjusted to create a particle having a controlled size and net-zero, -positive, or -negative charge.

# Declaration and Power of Attorney For Patent Application

## English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

### **METHODS AND COMPOSITIONS OF GENE DELIVERY AGENTS FOR SYSTEMIC AND LOCAL THERAPY**

the specification of which

(check one)

is attached hereto.

was filed on \_\_\_\_\_ as United States Application No. or PCT International

Application Number \_\_\_\_\_

and was amended on \_\_\_\_\_

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, or plant breeder's rights certificate(s), or 365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

### Prior Foreign Application(s)

### Priority Not Claimed

(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/>
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I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

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60/425,379

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November 12, 2002

(Application Serial No.)

(Filing Date)

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(Application Serial No.)

(Filing Date)

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(Application Serial No.)

(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

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(Application Serial No.)

(Filing Date)

(Status)

(patented, pending, abandoned)

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(Application Serial No.)

(Filing Date)

(Status)

(patented, pending, abandoned)

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(Application Serial No.)

(Filing Date)

(Status)

(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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 Judith M. Riley, 31,561  
 Douglas J. McEvoy, 34,385  
 John G. Posa, 37,424

Avery N. Goldstein, 39,204  
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 Mark D. Schneider, 43,906  
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Fifth inventor's signature	Date
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**PATENT MS: PAT. APPL.**

The received stamp of the U.S. Patent and Trademark Office imprinted hereon acknowledges the filing of:

Transmittal Letter  New Patent Application (*Claims present*)  
27 Page(s) Specifications 5 Page(s) Claims  
1 Page(s) Abstract 7 Sheets of Drawings  
 Small Entity Declaration  Declaration & Power of Atty  
 IDS, PTO 1449 & Patents  Assignment & Recordation Cover Sheet  
 Amendment/Response  Check # 473-22

Other: Application Data Sheet

Inventor: John Hilfinger et al.

Serial/Reg. No. 10002138 Atty Docket No. TSR  
Date: Nov. 12, 2003 Date Due: Nov. 12, 2003  
 Cert. of Mailing/Express Mail Label No. EL 983172102 US

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PATENT MS: PAT. APP

The receiver  U.S. Patent and Trademark Office  *Claims paper*  *Transmittal Letter*  *New Patent Application*  *27 Page(s) Specifications*  *5 Page(s) Claims*  *1 Page(s) Abstract*  *7 Sheets of Drawings*  *Small Entity Declaration*  *Declaration & Power of Atty*  *IDS, PTO 1449 & Patents*  *Assignment & Recordation Cover Sheet*  *Amendment/Response*  *Check # 4732 C2141 U.S. P.T.O.*  *10/706738*

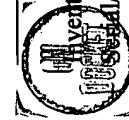
Other: Application Data Sheet

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Att'y Docket No. MSR-100828  
Date: Nov. 12, 2003 Date Due: Nov. 12, 2005

Cert. Of Mailing/Express Mail Label No. EL 98317210245



Inventor: John Hilfinger et al.

Atty/Reg. No. MSR-100828

Date: Nov. 12, 2003

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: John Hilfinger et al.

Serial No.: 10/706,738

Filing Date: November 12, 2003

For: METHODS AND COMPOSITIONS OF GENE DELIVERY  
AGENTS FOR SYSTEMIC AND LOCAL THERAPY

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DECLARATION OF JANICE R. KUEHN

Janice R. Kuehn declares as follows:

1. I am a legal assistant for the patent law firm of Gifford, Krass, Groh, Sprinkle, Anderson & Citkowski, P.C. I have been employed by this firm since November 1996.
2. In my present position I am secretary to patent attorneys Avery N. Goldstein and Angela M. Davison. In that capacity I prepare patent application submission documents to be filed with the U.S. Patent and Trademark Office.
3. In my capacity, when preparing a United States utility patent application, I print final versions of the transmittal pages, application data sheets, specification, claims and abstract. I also assemble the declarations and drawings which may or may not be in digital form. It is a standard procedure that the specification, claims and abstract are all contained within a single document in Word format (Microsoft Corporation). The transmittal pages and application data sheet are prepared using LegalStar IP Forms and EPAVE software from the USPTO, respectively. The computer-printed documents are always the documents submitted to the Patent Office, with copies being made for our file and the client. Thus, if a copying error occurred, it

would appear in our file, not at the Patent Office. In this instant case, the file copy and client copy are complete.

4. In the process of preparing the transmittal papers, necessary to fill out the fee calculation and transmittal fields I prepare a tally of the total number of claims, total number of independent claims, and the numbering of the independent claims. On this same piece of paper I also run a tally of total numbers of pages corresponding to transmittal papers, declaration, application data sheet, specification, claims, abstract and drawings.

5. In preparing to actually mail an application to the United States Patent and Trademark Office I use this tally sheet to finally count the number of pages corresponding to each portion of the submission and further to fill out the return receipt postcard that accompanies the submission. The tally sheet used in this particular patent application submission is attached at Appendix 1 to this declaration. The attached tally sheet includes an error of 28 pages of specification, 5 pages of claims, and one page of abstract. As this tally sheet was used to fill out the transmittal pages, page 1, section 2 noting the specification having 34 pages, the error as to the specification having 28 pages instead of the actual number of 27 appears in the line stating that the specification has 34 pages. Additionally, the total pages in the submission noted as being 52 in the upper left-hand corner of the transmittal pages indicating 52 pages is likewise in error based on a miscount at the tally sheet stage of the submission preparation.

6. The final document of the submission package I complete is the return receipt postcard for which I perform a separate count of specification pages, claim pages, pages of abstract, and drawing pages. While it is certainly possible as happened in this case that a one page discrepancy in a specification may not be caught in this final count, I cannot imagine a

scenario by which an entire section, namely five pages of claims constituting the full set of claims, would be omitted from a utility patent application submission.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the subject patent.

Date: April 13, 2004

Janice R. Kuehn  
Janice R. Kuehn

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APPLICATION NUMBER	FILING DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	DRAWINGS	TOT CLAIMS	IND CLAIMS
60/425,379	11/12/2002	80		TSR- 10081/38		7	

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Date Mailed: 12/18/2002

Receipt is acknowledged of this provisional Patent Application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please write to the Office of Initial Patent Examination's Filing Receipt Corrections, facsimile number 703-746-9195. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).

**Applicant(s)**

Phillip Kish, Ann Arbor, MI;

**If Required, Foreign Filing License Granted:** 12/18/2002

**Projected Publication Date:** None, application is not eligible for pre-grant publication

**Non-Publication Request:** No

**Early Publication Request:** No

**\*\* SMALL ENTITY \*\***

**Title**

Methods and compositions gene delivery agents for systemic and local therapy

**LICENSE FOR FOREIGN FILING UNDER  
Title 35, United States Code, Section 184  
Title 37, Code of Federal Regulations, 5.11 & 5.15**



TSR-10081/38  
21111gs/jk

**METHODS AND COMPOSITIONS GENE DELIVERY  
AGENTS FOR SYSTEMIC AND LOCAL THERAPY**

**Field of the Invention**

The present invention relates to gene therapy and more particularly to  
5 drug delivery molecules for delivering various nucleic acids compositions to  
the lumen of the intestine or to localized tissues.

**Background of the Invention**

Gene therapy has garnered considerable attention as a method to treat  
various human diseases by the enhancement of protein production. These  
10 include gene replacement or gene augmentation.

This invention allows the performance of *in vivo* gene therapy by oral  
and other methods.

This invention provides for a method to perform systemic therapy for  
various mammalian conditions. Tables 2-4 in the Appendix describe some of  
15 the possible proteins, classes of proteins and potential disease conditions  
amenable to gene therapy.

Methodology review of other gene therapy delivery strategies, which  
utilize mechanical direct injection or particle bombardment, recombinant  
viruses and liposomes that are dependent on receptor-mediated endocytosis.

20 Oral therapy is easy to administer, generally the least expensive, and  
has good patient compliance for dosing.

Difficulties in this method:

Epithelial cells have a 2-4 day turnover rate, meaning short duration of  
expression of transformed cells.

Mucus layer may further reduce the amount of the cellular exposure and reduce transformation efficiency.

The intestine routinely degrades large amounts of foreign DNA ingested in our food. The presence of DNases in the intestinal tract can 5 provide a significant barrier to entry of intact DNA into intestinal tract cells.

#### Brief Description of the Drawings

Figure 1. Transmission electron microscopy (TEM) of BAC/pDNA complex.

Figure 2. Measurement of BAC / plasmid DNA particle formation.

10 Figure 3. Measurement of BAC<sub>condensed</sub> plasmid DNA particle size in simulated gastric or intestinal fluid.

Figure 4. BAC/pDNA Particle Zeta Potential Measurements.

Figure 5. Endonuclease Protection Assay.

15 Figure 6. *In vitro* transfection of Hela cells with BAC/luciferase pDNA.

Figure 7. *In situ* perfusion of radiolabeled BAC/pDNA in intestinal segments.

#### Detailed Description of the Preferred Embodiments

The invention involves methods and products for oral and parenteral gene delivery for both systemic and localized therapy. These contain, in non- 20 covalently bound form, one or more substances having an affinity for nucleic acid, which are capable of increasing the efficiency of absorption of the complexes into the cells. Cells of a mammalian subject (either intestinal

epithelia after oral delivery, or cells in other organs after parenteral delivery) are altered to operatively incorporate a gene, which expresses a protein, which is secreted directly into the organ and/or blood stream to provide a therapeutic effect. The use of naked nucleic acid protected by complexation with adsorption/internalization factors avoids the complications associated with use of viral vectors to accomplish gene therapy. These complexes can be delivered via the intestinal lumen in a variety of ways, including through timed-release capsules, thereby obtaining a simple, noninvasive method of gene delivery for gene therapy. These complexes can also be delivered to other organs of the body in a variety of ways, including direct injection or infusion. After oral delivery the transformed intestinal epithelial cells provide short or long term therapies for diseases associated with a deficiency in a particular protein or which are amenable to treatment or palliation by over expression of a protein including metabolic disorders, endocrine disorders, circulatory disorders, coagulation disorders, cancer, and gastrointestinal disease.

The targeting-internalizing conjugate is preferably a bile acid conjugated with a poly cationic peptide linked to the bile acid steroid backbone. The bile acid moiety acts to target the conjugate to bile acid transporters in the lumen of the intestine and assist in the cellular internalization of the complex. Short polycation peptides rich in arginine (e.g. 6-arginine amino acids) provide multiple functions; a) having an affinity for nucleic acid, b) act condensing agent, c) protect the nucleic acid from nuclease activity and d) assist in cellular internalization of the complex.

Conjugation of the cationic polypeptide chain to the bile salt can be made through the hydroxyl groups in the 3, 7, or 12 positions of the bile acid steroid nucleus, or on the 24-carboxyl group of the bile acids.

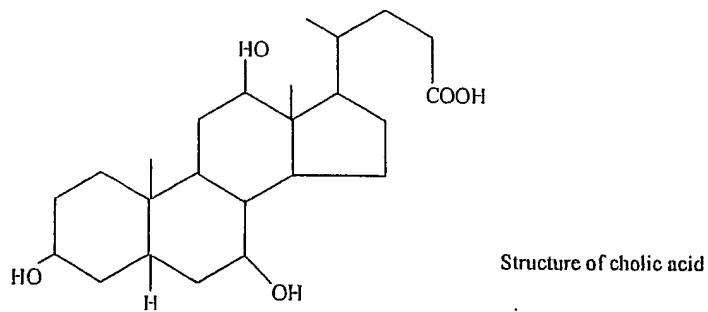
Composition of the polypeptide nucleic acid condensing moiety can be 5 altered to vary the affinity to the nucleic acid, providing changes in the rate of intracellular decondensing of the nucleic acid. The number of amino acids in the polypeptide can be varied and be composed primarily of arginine with neutral and acidic amino acids to act as spacers and linkers to the bile acids.

One aspect of the invention relates to cationic derivatives of the bile salt 10 acids such as cholic acid with peptides containing multiple arginine amino acids as in Formula I.



wherein:

R<sub>1</sub> is cholic acid (5β-CHOLANIC ACID-3α, 7α, 12α - TRIOL) or one of its 15 analogues;



X is a linker peptide with either a negative, neutral or positive charge

Z is a cationic peptide

In related aspects, the invention provides polyanion-bile acid complexes comprising the bile acid – amino acid conjugates of Formula I, methods of

their preparation and their use in delivering biologically active substances to cells.

There are several advantages of the present invention:

One advantage is that expressed protein can be secreted into the  
5 circulatory system to provide a systemic effect.

Another advantage of the present invention is that the gene expression can be regulated by the administration of the invention. Because the epithelia of the intestine are sloughed into the lumen every few days, the gene expression remains transient.

10 Another advantage is that the potential side effects, which may be severe, are avoided, or minimized by the rapid turnover of intestinal epithelial cells. Additionally, the use of naked DNA with a chemical conjugate avoids the antigenic reactions associated with gene therapy with viral vectors or electroporation of DNA into cell.

15 Another advantage of this invention is that the method completely avoids invasive procedures. The nucleic acids are orally administered in the form of a capsule, pill or other oral preparation.

In another embodiment, the selected nucleic acid is, or encodes, an RNA molecule comprising an *antisense* which blocks expression of a gene,  
20 e.g., in a tumor cell. By blocking expression of this selected gene, inhibition of growth is observed for the tumor.

In another embodiment, this oral delivery system can deliver ribozymes. A ribozyme is a catalytic RNA molecule that cleaves other RNA

molecules (e.g., mRNA transcripts in a cell) having particular nucleic acid sequences. Common targets include RNAs comprising GUC or GUA subsequences. For example, hairpin ribozymes typically cleave one of two target sequences. GUC hairpin ribozymes cleave an RNA target sequence consisting of NNNBCN\*GUCNNNNNNN (SEQ ID NO: 1) (where N\*G is the cleavage site, B is any of G, U or C, and where N is any of G, U, C, or A). GUA ribozymes typically cleave an RNA target sequence consisting of NNNNN\*GUANNNNNNNN (SEQ ID NO: 2) (where N\*G is the cleavage site and where N is any of G, U, C, or A). See, De Young et al. (1995) Biochemistry 34: 15785-15791. Ribozymes optionally comprise non-standard ribonucleotide bases, or deoxyribonucleotide bases, which can stabilize the ribozyme and make it resistant to RNase enzymes. Alternatively, the ribozyme can be modified to a phosphothio analog for use in this *delivery* system. This modification also renders the ribozyme resistant to endonuclease activity.

In another embodiment of the present invention, incorporation of other molecules such as the amino acid sequence of the 12-residue membrane-translocating peptide (Ala-Ala-Val-Leu-Leu-Pro-Val-Leu-Leu-Ala-Ala-Pro) can be incorporated into this polyplex to either target, increase adsorption, internalization or nuclear localization of the polyplex. As used herein, however, the term “peptide” is intended to include mimetics and the term “amino acid” is intended to include D-form amino acids and modified amino acids.

**Examples**

**Example 1**

**Method for synthesis of bile acid conjugates (BAC)**

BAC is synthesized by solid phase chemistry on a peptide synthesizer.

5 A six L-arginine peptide was first synthesized on the resin bed using standard 9-fluorenylmethoxycarbonyl (FMOC) chemistry. To attach the bile acid salt an excess of chendoxycholic acid was added to the resin and allowed to react with the immobilized peptide. After conjugation, BAC was cleaved from the resin and purified to greater than 95% purity by HPLC.

10 **Example 2**

**Construction of Expression Plasmids**

An expression plasmid using an optimized Cytomegalovirus (CMV) early promoter-enhancer to drive transgene expression (pCF1) was utilized. For cell localization and transfection expression experiments the firefly luciferase cDNA was used as a reporter transgene (pCF1-luc). Plasmid backbones which are chosen to contain the origin of replication and an antibiotic resistance gene or other selectable marker allowing the growth and maintenance of the plasmid in its bacterial host. Other attributes to facilitate the production of plasmid DNA are: 1) the ability of the plasmid to produce high copy number in the host bacteria; 2) a eukaryotic transcriptional promoter to initiate the synthesis of mRNA when it enters the target cells; 3) the DNA coding sequence encoding the protein of interest with a translational start codon (ATG) in the sequence for initiation of protein synthesis and a stop

20

codon to terminate translation; and 4) an optional transcription termination sequence.

### **Example 3**

#### **Preparation of BAC/pDNA Complexes**

5       Typically an equal volume of BAC solution at 3 mg/ml (2.25 mM) was slowly added with mixing to a pDNA solution at a concentration of 250 $\mu$ g/ml to form a neutrally charged complex. Mass spec analysis has provided evidence that the major ionic species in the BAC has a charge of +3 per BAC molecule (MW = 1329) under neutral conditions (data not shown). Assuming  
10      a charge of -2 per base pair of the 4550 bp pDNA (MW = 3,003,000). (Total DNA charge = -9100), a net neutral charge would theoretically require a ratio of about 3033:1 (BAC:pDNA). Physical measurements of the BAC/pDNA complex appear require about 10-fold more BAC to neutralize the pDNA charge (see Table I). The presence of buffer salts bound to the BAC during  
15      synthesis and purification may partially explain this observation.

**Table I**

<b>BAC amount <math>\mu</math>g/ml</b>	<b>BAC:pDNA molar ratio</b>	<b>Particle Charge determined by Zeta Potential</b>
50	8070:1	Negative
200	32,280:1	Neutral
2000	322,799:1	Positive

**Example 4**

**BAC condenses plasmid DNA.**

The ability of BAC to condense DNA was determined using transmission electron microscopy (TEM). TEM of a BAC/pDNA particle complex is shown in Figure 1. The mole ratio of BAC:pDNA was 1581:1, which retained a net negative charge on the particle. The samples after mixing were diluted in water, and a drop applied to the carbon-coated formvar-film grid. These were dried, stained and observed in a TEM scope. Even at this low molar ratio of BAC:pDNA clear rod shaped particles (toroids) were formed.

**Example 5**

**BAC condensed plasmid DNA forms discrete particles.**

NICOMP particle size analysis is shown in Figure 2. 1 ml of 14 ug/ml DNA plasmid was mixed with 1 ml of BAC at the concentrations shown in Table 1. Also shown are the calculated molar ratios and particle charges.

Particle sizes were measured at a specific time after mixing of the pDNA with the BAC.

Figure 2 panels a-d show some representative results of these experiments. Mixtures of pDNA and BAC start forming particles immediately. However, with increasing time these particles appear to aggregate, so that at later times particles larger than 1  $\mu\text{m}$  were observed.

**Example 6**

**BAC condensed plasmid DNA particle size in simulated gastric or intestinal fluid.**

The behavior of the pDNA/BAC complex in buffers with different pH's  
5 to simulate gastric fluid (SGF) or intestinal fluid (SIF). pDNA and BAC  
(BAC:pDNA: = 80,699:1, slightly positive charge) were mixed first in water  
and then mixed with the same volume of simulated gastric fluid (SGF, 0.1 M  
HCl, pH 1.2) or simulated intestinal fluid (SIF, 0.05 M phosphate buffer, pH  
6.8). Measurements were made after two hours incubation at 37°C. After 2  
10 hours, most of the DNA complexes in water (Figure 3a) and SIF (Figure 3b)  
were observed to be greater than 1 um in size. However, over 30% of DNA  
complex incubated in SGF (Figure 3c) were observed to be under 1 um size.  
These results indicate that pH has some effect on the physical behavior of  
BAC/pDNA complexes.

**Example 7**

15 **Measurement of the zeta potential** (net charge) of the particle  
complexes were made after mixing BAC/pDNA in water. Additional aliquots  
of BAC were added and the zeta potential remeasured (Figure 4).

**Example 8**

DNase protection assays - The ability for BAC complex formation to  
20 protect DNA from endonuclease activity was examined. We have utilized the  
ability of polyanions such as polyaspartic acid (PAA) to competitively  
dissociate the polycations from DNA (33).

- 1) The mixture of luciferase BAC/pDNA was stored at room temperature for 2.5 hours (BAC/pDNA: = 9038:1).
- 2) 10  $\mu$ l of 10 mg/ml PAA or milli-Q water was added to each sample (5  $\mu$ l of DNA complex mixture) and stored at room temperature for 2 hours.
- 5 3) The molar ratio was (DNA:BAC:PAA= 1:9038:13,572), the charge ratio (DNA:BAC:PAA=1:3:388), assuming BAC has 3 positive charges and PAA has 260 negative charges.
- 4) 5  $\mu$ l of 100 kunit/ml DNaseI or milli-Q water was added to each sample and those samples were incubated at 37°C for 15 min and heated at 70°C for 15  
10 min.
- 5) 2  $\mu$ l of 500 mM EDTA and 1  $\mu$ l of 5% SDS were added to each sample and heated at 55°C for 3 hours to dissociate the BAC from the pDNA. Samples were then electrophoresed in an agarose gel and stained with ethidium bromide (Figure 5).

15 **Conclusions from DNase protection assays:** Extremely harsh conditions are required to dissociate BAC from the BAC/pDNA complex (1% SDS at 55°C for 2 hours, 1 hour was not enough to reach a plateau dissociation level, data not shown).

20 DNaseI together with BAC in the mixture altered the effect the dissociation by SDS (Lane 2). The DNA sample which was incubated at 37°C for 15 min with DNaseI showed almost complete fragmentation (Lane 3). The BAC/pDNA sample incubated in the presence of PAA and DNaseI showed

less intact DNA banding (Lane 1) than BAC/pDNA samples with or without treatment with PAA (Lanes 4 & 5 respectively).

These results show that DNA was protected by BAC from DNaseI activity.

5      Example 9

***In Vitro Transfection Assays:*** To examine the capability of the BAC/pDNA complexes to transfect cells *in vitro*, we examined the ability of BAC to transfect Hela tissue cultures using the firefly luciferase gene. In transient transfection assays (24 h), BAC enhanced the transfection efficiency in combination with liposomes (data not shown). But, more interesting was the ability of the BAC/pDNA to transfect Hela cells alone as a single agent (Figure 6). The charge ratio was approximately neutral. This experiment has not been optimized. The approximate molar ratios are indicated in parenthesis.

Example 10

***In Situ Intestinal Absorption:*** In order to examine the capability of the BAC/pDNA complex to bind and/or be absorbed onto the intestinal lumen cells we tested the absorption of nicked-radiolabeled pDNA in a single pass perfusion experiment. Using isolated ileal or jejunal segments radio-labeled BAC/pDNA mixtures mixture was mixed with HEPES buffer, pH 7.4, and perfused at jejunal and ileal sites. After 30 min of steady state, sample fractions were collected and the absorbed fraction of BAC/pDNA calculated. BAC/pDNA mixture used were (pDNA:BAC= 1:0 negatively charged, 1:27,000 neutrally charged, 1:54,000 positively charged).

15

Between 20-40% of the “neutrally charged” BAC/pDNA complex was absorbed in a single pass of the intestine (Figure 7). If true, then we would expect that this complex should be completely absorbed after oral dosing. The mechanism of this absorption, whether by binding to specific transporters such as the ileal bile acid transporter or by a non-specific mechanism remains to be determined.

Patent applications and publications mentioned in the specification are indicative of the levels of those skilled in the art to which the invention pertains. These applications and publications are incorporated herein by reference to the same extent as if each individual application or publication was specifically and individually incorporated herein by reference.

The foregoing description is illustrative of particular embodiments of the invention, but is not meant to be a limitation upon the practice thereof. The following claims, including all equivalents thereof, are intended to define the scope of the invention.

What is claimed is:

Claims

1           1. A method for increasing the blood levels of secretable  
2 therapeutic proteins in mammals, the method comprising: introducing a  
3 formulation into a target cell, the formulation comprising a DNA construct not  
4 packaged in a viral particle, wherein the construct encodes a functionally active  
5 protein polypeptide that mediates increasing the protein levels in the  
6 bloodstream.

1           2. The method of claim 1, wherein said introducing is by oral  
2 administration.

1           3. The method of claim 1, wherein functionally active protein is  
2 delivered to the bloodstream for a period of from about two to four days.

1           4. The method of claim 1, wherein the target cell is a  
2 gastrointestinal cell other than an intestinal stem cell.

1           5. The method of claim 5, wherein the gastrointestinal cell is  
2 within the small intestine.

1           6. The method of claim 5, wherein the gastrointestinal cell is a cell  
2 within the large intestine.

1           7. The method of claim 1, wherein said introducing is by  
2 parenteral administration.

Appendix

Table 2

Exemplary Proteins for Gene Therapy

Insulin	interferon-alpha.2B	human growth hormone (hGH)
transforming growth factor (TGF)	erythropoietin (EPO)	ciliary neurite transforming factor (CNTF)
clotting factor VIII	insulin-like growth factor-1 (IGF-1)	bovine growth hormone (BGH)
granulocyte macrophage colony stimulating factor (GM-CSF)	platelet derived growth factor (PDGF)	interferon-alpha.2A
clotting factor VIII	brain-derived neurite factor (BDNF)	thrombopoietin (TPO)
insulintropin	tissue plasminogen activator (tPA)	
IL-1	IL-2	urokinase
IL-1 RA	streptokinase	superoxide dismutase (SOD)
adenosine deamidase	catalase	calcitonin
arginase	fibroblast growth factor (FGF) (acidic or basic)	neurite growth factor (NGF)
phenylalanine ammonia lyase	granulocyte colony stimulating gamma.- interferon factor (G-CSF)	L-asparaginase
pepsin	uricase	trypsin
chymotrypsin	elastase	carboxypeptidase
lactase	sucrase	intrinsic factor parathyroid hormone (PTH)-like hormone
calcitonin	Ob gene product	cholecystokinin (CCK)
glucagon	glucagon-like-peptide I (GLP-1)	insulinotropic hormone

**Table 3**  
**Exemplary Classes of Proteins for Gene Therapy**

proteases	pituitary hormones	protease inhibitors
growth factors	cytokines	somatomedians
chemokines	immunoglobulins	gonadotrophins
interleukins	chemotactins	interferons
lipid-binding proteins		

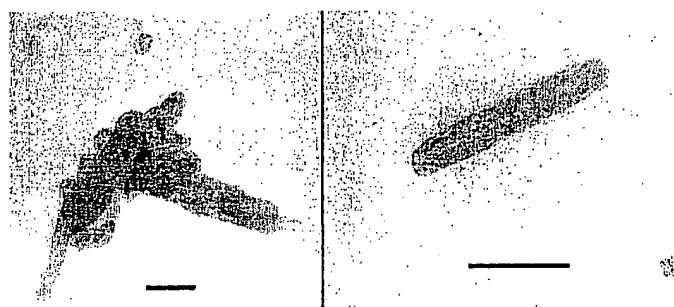
Various disease conditions are amenable to treatment using the gene therapy of the invention. One skilled in the art can recognize the appropriate protein that should be produced by the invention for treating specific disease conditions. Exemplary diseases that are amenable to treatment using the subject invention, and exemplary, appropriate proteins which can be used in treating these diseases, are shown in Table 3.

**Table 4**  
**Exemplary Disease Conditions or Deficiencies Amenable to Gene Therapy**

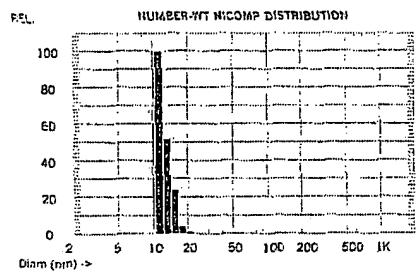
Enzyme Deficiency	Erythropoietin	Catalase
Endotoxic Shock/Sepsis	Adenosine deaminase (For treatment of severe combined immunodeficiency)	Lipid-binding protein (LBP)
Purine nucleotide phosphorylase	Galactosidase	beta-glucuronidase
Antioxidants for Cancer	Therapy Anemia	Superoxide dismutase
Cancer		Growth Factors (for use in wound healing, induction of red blood cell formation, etc.)
alpha.-Interferon	beta.-Interferon	Epidermal growth factor
Granulocyte colony stimulating factor (G-CSF)	alpha-IL1	gamma-Interferon
Phenylalanine ammonia lyase	Transforming growth factor	Arginase
Erythropoietin	L-asparaginase	Thrombopoietin
Uricase	Insulin-like growth factor-1	Insulin
Human growth hormone	Monoclonal antibodies	Tissue necrosis factor
Cardiovascular Disease	Diabetes	Tissue plasminogen activator

Urokinase (native or chimeric)	Glucagon	alpha..sub.1 -antitrypsin
Insulinotrophic hormone	Clotting disorders	Antithrombin-III
Other proteases or protease inhibitors	Clotting factor VIII	
Apolipoproteins (particularly B-48)	Circulating Scavenger Receptor	APO A1.( Converts low-density lipoproteins to high-density lipoproteins)
Gastrointestinal and Pancreatic Deficiencies	Obesity and Feeding	
Pepsin (for esophageal reflux)	Ob gene product	Cholecystokinin (CCK)
Trypsin	Chymotrypsin	
Bone diseases		
Elastase	Carboxypeptidase	Calcitonin
Lactase (for lactose deficiency)	PTH-like hormone	Sucrase
Intrinsic Factor (pernicious anemia)	Myasthenia gravis (acetylcholine receptors)	Graves' disease (thyroid-stimulating hormone receptor)
Organ-Specific Autoimmune diseases (target of antibody in parentheses)	Thyroiditis (thyroid, peroxidase)	Insulin-resistant diabetes with acanthosis nigricans or with ataxia telangiectasia (Insulin receptor)
Allergic rhinitis, asthma (Beta..sub.2 -adrenergic receptors)	Juvenile insulin-dependent diabetes (insulin, GAD65)	Pernicious anemia (gastric parietal cells, vitamin B..sub.12 binding site of intrinsic factor)
Addison's disease (adrenal cells)	Idiopathic hypoparathyroidism (parathyroid cells)	Spontaneous infertility (sperm)
Premature ovarian failure (interstitial cells, corpus luteum cells)	Pemphigus (intercellular substance of skin and mucosa)	Bullous pemphigoid (basement membrane zone of skin and mucosa)
Primary biliary cirrhosis (mitochondria)	Autoimmune hemolytic anemia (erythrocytes)	
Idiopathic thrombocytopenic purpura (platelet)	Idiopathic neutropenia (neutrophils)	Vitiligo (melanocytes)
Osteosclerosis and Meniere's disease (type II collagen)	Chronic active hepatitis (nuclei of hepatocytes)	Systemic Autoimmune Diseases (defect/organ affected in parentheses)
Goodpasture's syndrome (basement membranes)	Rheumatoid arthritis (.gamma.-globulin, EBV-related antigens, collagen types II and III)	Sjogren's syndrome (.gamma.-globulin, SS-A (Ro), SS-B (La))

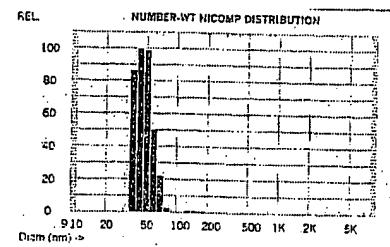
Systemic lupus erythematosus (nuclei, double-stranded DNA, single-stranded DNA, Sm ribonucleoprotein, lymphocytes, erythrocytes, neurons, gamma-globulin)	Scleroderm (nuclei, Scl-70, SS-A (Ro), SS-B (La), centromere)	Polymyositis (nuclei, Jo-1, PL-7, histadyl-tRNA synthetase, threonyl-tRNA synthetase, PM-1, Mi-2)
Rheumatic fever (myocardium heart valves, choroid plexus)		



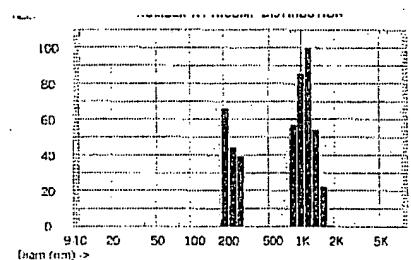
**Figure 1.** TEM of BAC/pDNA complex. A negatively charged mixture of BAC/pDNA was applied to a carbon-coated formvar-film grid and allowed to dry. The samples were stained with uranyl acetate before viewing. Bars are 100 nM long.



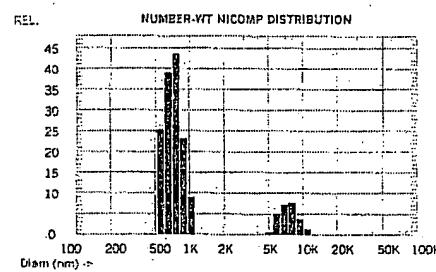
**Figure 2a – Particle sizing of pDNA only**



**Figure 2b - pDNA + 50ug/ml BAC.**  
Time until measurement after  
mixing 0 min.  
(complex is negatively charged)

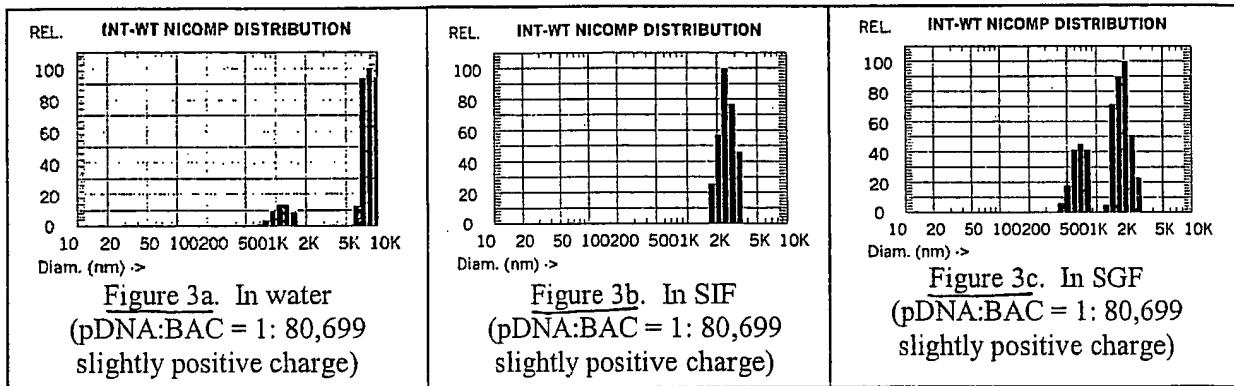


**Figure 2c - pDNA + 200ug/ml BAC.** Time until measurement after mixing 0 min.  
(complex is neutrally charged)

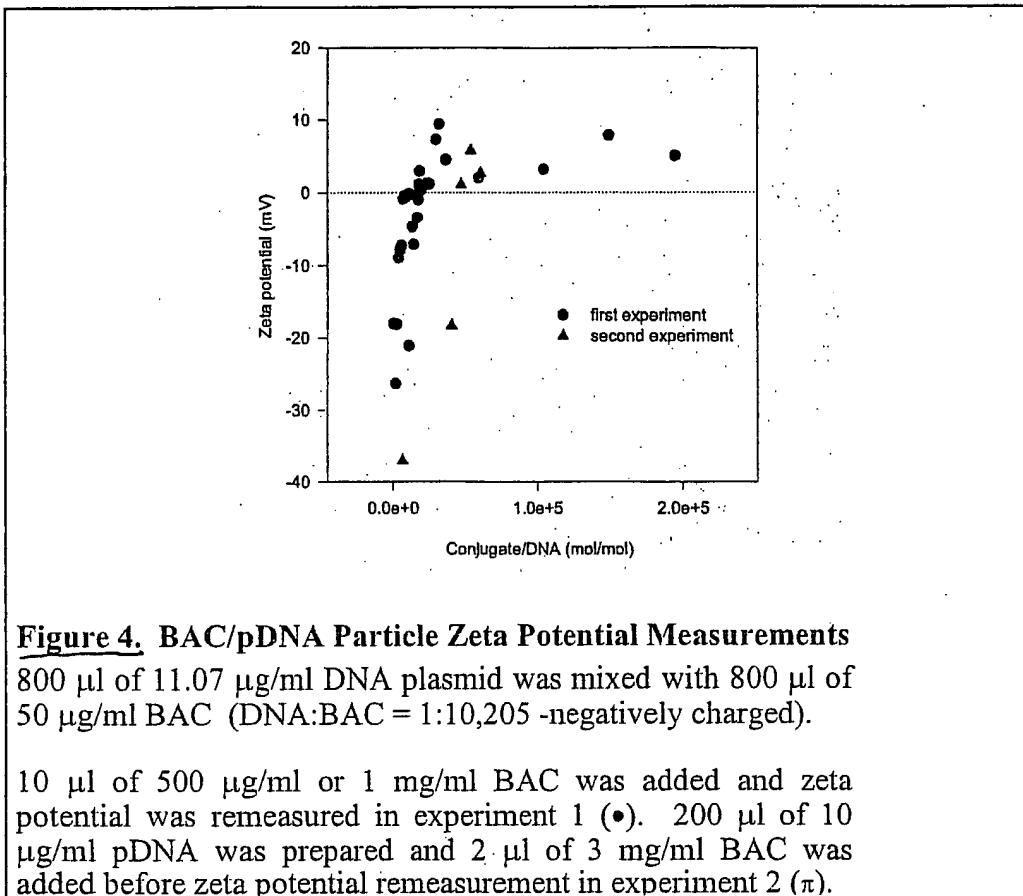


**Figure 2d - pDNA + 200ug/ml BAC.** Time until measurement after mixing 2 hours.  
(complex is neutrally charged)

**Figure 2. Measurement of BAC / plasmid DNA particle formation**

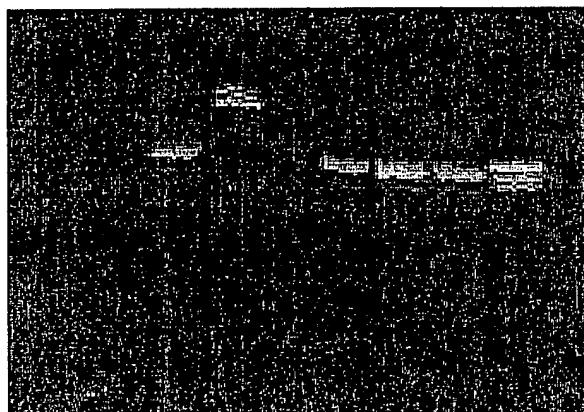


**Figure 3. BAC condensed plasmid DNA particle size in simulated gastric or intestinal fluid**



**Figure 5. Endonuclease Protection Assay**

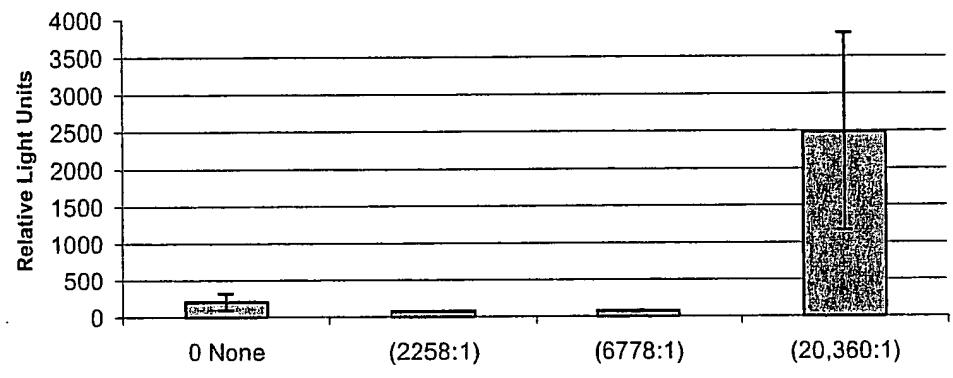
Lanes      1    2    3    4    5    6    7



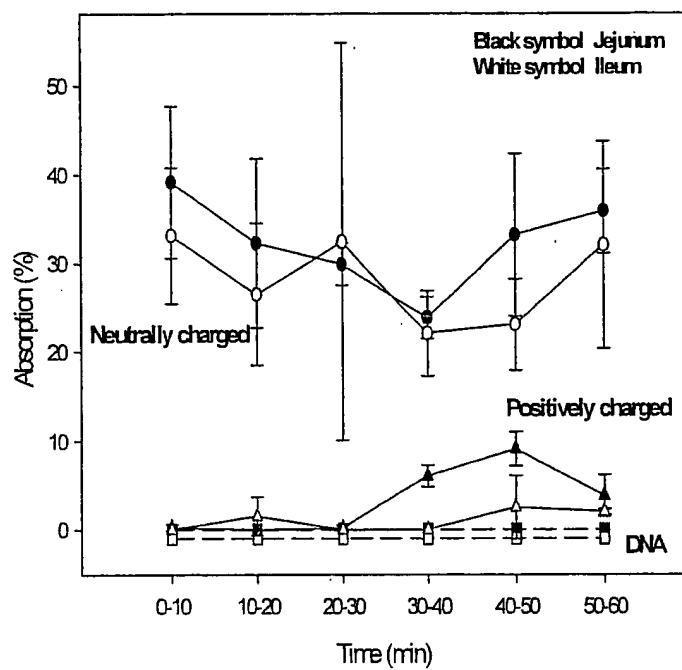
Lanes

- 1) DNA + BAC + PAA + DNaseI
- 2) DNA + BAC + DNaseI
- 3) DNA + DNaseI
- 4) DNA + BAC + PAA
- 5) DNA + BAC
- 6) DNA
- 7) DNA size standard

**Figure 6 - Hela Transfection with BAC/pDNA**



**Figure 6.** *In vitro* transfection of Hela cells with BAC/luciferase pDNA.



**Figure 7.** *In situ* perfusion of radiolabeled BAC/pDNA in intestinal segments.